# THE EFFECT OF STROKE TYPE, STAGE OF COMPETITION AND FINAL RACE POSITION ON PACING STRATEGY IN 200M SWIMMING PERFORMANCE.

**by**

**Daniel Ward**

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No portion of the work referred to in this Research Project has been submitted in support of an application for another degree or qualification of this, or any other University or institute of learning.

The project was supervised by a member of academic staff, but is essentially the work of the author.



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**Abstract**

The purpose of this study was to investigate the effect of stroke types, final race position and stage of competition on pacing strategy in elite women's 200m swimming performance, and to appraise medallist's stroke rate (SR) and stroke length (SL). Elite women's 200m backstroke, breaststroke, butterfly, and freestyle performances (n = 576) formed twenty-four groups based on stroke type, final race position (medallists/non-medallists) and stage of competition (heats/semi-final/final). A mixed design with independent groups (stroke type/final race position) and repeated measures (stage of competition) was used. Official race and 50m split times were converted to velocities and normalised to average to show pacing strategy. Medallists SR and SL (n = 68) were quantified using a bespoke software. Kruskal-Wallis test and Mann-Whitney U tests (post hoc) appraised significant differences between stroke types, multiple Mann-Whitney U tests appraised significant differences in final race position. Finally, Friedman test and multiple Wilcoxon tests (post hoc) appraised significant differences between both stages of competition and 50m splits. Generally, split times showed significant differences between splits ($p<0.05$, ES = 0.41-0.88) and normalised velocity showed significant differences between stroke type ($p<0.05$, ES = 0.33-1.10). Whereas, normalised velocity reported no significant differences regardless of final race position or stage of competition ($p>0.05$). Medallists SR and SL showed significant differences between splits ($p<0.05$, ES = 0.10-0.51) and stroke type ($p<0.05$, ES = 0.35-0.82). It was concluded that pacing strategies were dependent on stroke used with 'fast start-even' (backstroke/freestyle) and 'positive' (breaststroke/butterfly) reported, however, pacing remained consistent regardless of final race position or stage of competition. The differences were underpinned by stroke mechanics and changes in SR and SL.

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## 1. Introduction

Swimming is a cyclic sport consisting of start, turn and free swim elements (Veiga, Cala, Frutos & Navarro, 2014) and athletes aim to complete set distances in the shortest time using one of four permitted strokes (backstroke, breaststroke, butterfly and freestyle) (Saavedra, Escalante, Garcia-Hermoso, Arellano & Navarro, 2012). Swimming requires efficient energy distribution to prevent fatigue, a concept referred to as pacing (McGibbon, Pyne, Shepard & Thompson, 2018). Pacing is the conscious or subconscious regulation of energy or work according to a predetermined plan to maximise performance and prevent physiological harm (McGibbon et al., 2018; Saavedra et al., 2012). Effective pacing is a prerequisite of successful swimming performance (McGibbon et al., 2018; Robertson, Pyne, Hopkins & Anson, 2009) and several types of pacing strategy are evident in swimming (appendix 1).

The unique demands from water immersion and low mechanical efficiency make pacing in swimming interesting to consider (Mauger, Neuloh & Castle, 2012; McGibbon et al., 2018). Despite the importance of pacing research remains limited (McGibbon et al., 2018), with more frequent focus upon, running (Mytton et al., 2015; Tucker, Lambert & Noakes, 2006), cycling (Corbett, 2009), speed skating (Muehlbauer, Schindler & Panzer, 2010a), triathlon (Le Meur et al., 2009), and rowing (Garland, 2005; Muehlbauer, Schindler & Widmer, 2010b). Due to limited research coaches routinely advise swimmers to adopt specific pacing strategies (Thompson, MacLaren, Lees & Atkinson, 2004), without quantitative evidence from competitions supporting these recommendations (Robertson et al., 2009). This highlighted that further investigation using information from elite competitions was warranted.

Pacing in swimming has different quantification methods, commonly pacing is reflected in official 50m split times (Lipinska, Allen & Hopkins, 2016; Robertson et al., 2009; Taylor, Santi & Mellalieu, 2016), however, split times are often considered too simplistic (Abbiss & Laursen, 2008). Other methods are velocity (displacement/time) (Stanula, Ostrowski, Strzata, Roczniok & Maszczyk, 2016) or normalised velocity whereby each split velocity is expressed as a percentage of the race average (Mauger et al., 2012; Skorski, Faude, Caviezel & Mayer, 2014). Normalised split velocity is a widely accepted method that future research should utilise to enable relative comparisons between groups (Mauger et al., 2012; McGibbon et al., 2018).

Generally, these methods characterise swimming pacing strategies as 'fast start', this owes to the dive start which has a velocity twice that of free swimming reducing split times by ~1-3 seconds (Kiuchi, Nakashima, Cheng & Hubbard, 2010; Robertson et al., 2009). Pacing varies depending on race distance, 'all out' strategies are effective in 50m events (Abbiss & Laursen, 2008; McGibbon et al., 2018) and 'positive' strategies effective in 100m events (Maglischo, 1993; Robertson et al., 2009; Thompson, Haljand & MacLaren, 2000). Whereas, in 200m events, 'fast start-even' was commonly reported (Maglischo, 1993; Robertson et al., 2009; Skorski et al., 2014; Stanula et al., 2016). In longer distance events 'negative' (400m), and 'even' (800m+) were more effective despite 'parabolic' (400m/800m) and 'fast start-even' (400m) having been more common (Abbiss & Laursen, 2008; Damasceno et al., 2013; Lipinska et al., 2016; Maglischo, 1993; Mauger et al., 2012; Robertson et al., 2009; Skorski et al., 2014; Taylor et al., 2016). The 200m events with durations from ~119 to ~147 seconds (Robertson et al., 2009) are of interest as information and understanding pertaining to events ~90-120 seconds is currently scarce

(Abbiss & Laursen, 2008). Secondly, these events allow comparisons between strokes.

Strokes can be categorised as alternating, whereby, one arm is in the propulsive phase as the other recovers (backstroke and freestyle) or simultaneous whereby, both arms are in either the propulsive or recovery phase (breaststroke and butterfly) (Hellard et al., 2008). Evidence exists of differences between strokes in lap times (Robertson et al., 2009; Skorski et al., 2014), velocities (Hellard et al., 2008), mechanics (Maglischo, 1993), start positions and type of turn performed (McGibbon et al., 2018). To date, pacing studies commonly focus on one stroke (Lipinska et al., 2016; Mauger et al., 2012; Stanula et al., 2016; Taylor et al., 2016; Thompson et al., 2003, 2004), therefore, creating a gap in the literature for studies appraising different pacing strategies across multiple strokes.

Contradicting research has shown swimsuits impact (Mytton et al., 2015) and have no impact on pacing strategy (Mauger et al., 2012). Polyurethane swimsuits were permitted in 2008/2009 before being banned in 2010, the suits increased buoyancy, reduced water resistance and improved race time (Partridge, 2011; Tor, Pease & Ball, 2015; Yustres, Martin, Fernandez & Gonzalez-Rave, 2017). Many studies include data when swimsuits were permitted, therefore, do not control for the swimsuit worn (Mauger et al., 2012; Saavedra et al., 2012; Yustres et al., 2017). This creates demand for contemporary research (post 2010) ensuring any effects of polyurethane swimsuits are controlled (Mytton et al., 2015).

In addition to swimsuits worn, many swimming studies also fail to address final race position (Lipinska et al., 2016; Mauger et al., 2012; Skorski et al., 2014;

Stanula et al., 2016). Swimming studies that have appraised final race position are conflicting with differences (Mytton et al., 2015; Saavedra et al., 2012) and no differences (Robertson et al., 2009) in pacing strategy reported. In cross country, the runners make a tactical attempt replicate pacing strategies used by previous medallists (Hanley, 2014, 2018). Swimmers and coaches could benefit from a comparison of medallist's and non-medallists pacing strategies to inform these tactics. Furthermore, quantifying changes in kinematic factors underpinning medallist's velocity (stroke rate (SR) and stroke length (SL)) could also be insightful (Muehlbauer et al., 2010b). There is an inverse relationship and highly individualised optimal combinations of SR and SL (Chollet, Pelayo, Tourny & Sidney, 1996; McGibbon et al., 2018). Over time SR has changed (Hellard et al., 2008) leading to demand for a contemporary appraisal. Specifically, information pertaining to medallists SR and SL could be beneficial to profile successful elite performance for coaches and athletes to replicate.

Finally, stage of competition (e.g. heats, semi-final and final) influences swimming performance, faster final performances potentially owing to pacing strategy were reported (Pyne, Trewin, & Hopkins, 2004). Although, recent research conflicted these findings with similar pacing and higher velocity reported in finals (Skorski et al., 2014), therefore, further investigation is warranted.

Currently, the literature has limited comparison between stroke type, final race position and stage of competition with contemporary information relating to medallists SR and SL required. Therefore, the aims of the present study were to investigate the effect of stroke types, final race position and stage of competition on pacing strategy in elite women's 200m swimming performance and to appraise medallist's SR and SL.

## 2. Methods

### *2.1 Participants*

Elite female international long course (50m) performances (n = 576) from Olympic Games 2012/2016 and World Championships 2011-2017 in four events (200m backstroke, breaststroke butterfly, and freestyle) were included. A convenience sampling approach excluded relays and individual medleys. Ethical approval was granted by the University of Chester ethics committee (May 2018, appendix 2) and consent granted by British Swimming (appendix 3).

### *2.2 Design*

An observational descriptive study using retrospective analysis was conducted. Twenty-four groups consisting of four stroke types, two final race positions (medallists/non-medallists) and three stages of competitions (heats/semi-final/final) formed the independent variables. Pacing strategy (normalised 50m split velocity) formed the dependent variable. A mixed design approach was utilised with independent groups (events/final race position) and repeated measures (stage of competition). Stage of competition was repeated measures as only the finalist's performance in heats and semi-finals were included.

### *2.3 Procedures*

#### *2.3.1 Split Times*

For all performances, official 50m split times were extracted from the governing bodies (FINA) website (http://www.fina.org/results). Split times were processed in Excel and descriptive statistics of mean ± std dev (M ± SD) were calculated for each group.

### *2.3.2 Velocity*

Average race and 50m velocity were calculated by dividing displacement by split or total race time. To normalise, the split velocity was divided by average velocity across the race and multiplied by 100, to be expressed as the percentage change. The results were collated into 24 groups with M ± SD calculated.

### *2.3.3 Stroke Rate and Stroke Length*

Medallists' final performances (n = 68 with 4 omissions, appendix 4) were recorded poolside and analysed post competition by trained sport science practitioners, using a bespoke performance analysis software and template. The analysts were permitted to pause, rewind, and review in slow motion where necessary, operational definitions for SR and SL in each stroke type are provided (appendix 5). The SR was calculated as the number of stroke cycles divided by time taken (mins) and SL as the free swim velocity (meters per min) divided by SR. Both were normalised by dividing 50m split values by race average and multiplying by 100 to be expressed as a percentage of race average. This procedure was completed for each performance and average (M ± SD) taken in each stroke type.

### *2.4 Reliability*

Reliability was assumed for split times as data was extracted from the governing body website. For SR and SL, five 200m races were analysed once by the current author and compared to another trained analyst's results (inter-observer), after several days the author re-analysed the same races (intra-observer) (appendix 6). The methods of Cooper, Hughes, O'Donoghue and Nevill (2007) were adapted to test reliability with +/- 1 stroke$\cdot$min$^{-1}$ permitted for SR and +/- 0.1 m$\cdot$stroke$^{-1}$ permitted for SL. The results were deemed reliable as above

90% of the differences between the test and retest scores were within the reference values permitted (table 1). Furthermore, intra-observer test-retest showed 'gold standard' reliability with 95% of the differences within the reference values (Cooper et al., 2007).

**Table 1.** Reliability analysis for stroke rate and stroke length.

| Performance indicator | Median (sign test p) | Percentiles 2.5% | 97.5% | +/- Agreement (%) | Confidence interval (%) |
|---|---|---|---|---|---|
| Inter SR | -0.1 (0.4) | -1.06 | 1.21 | 90 | 76.8 to 103.1 |
| Inter SL | 0.005 (0.3) | -0.08 | 0.08 | 95 | 85.4 to 104.5 |
| Intra SR | 0 (0.5) | -0.60 | 0.65 | 100 | 100 to 100 |
| Intra SL | 0 (0.2) | -0.05 | 0.03 | 100 | 100 to 100 |

*2.5 Statistical Analysis*

Data was processed using Excel and descriptive statistics (M ± SD) produced. Statistical analysis was conducted using SPSS (Version 24, Chicago, USA). Normality of split times, normalised velocity, SR/SL, and normalised SR/SL was assessed via Shapiro-Wilk test ($p<0.05$), therefore, non-parametric tests were used.

Significant differences between independent variables were assessed (Split times, normalised velocity, SR/SL, normalised SR/SL). For differences between stroke types, the Kruskal-Wallis test were used with post hoc Mann-Whitney U tests. For differences in final race position multiple Mann-Whitney U test were employed. Finally, differences between stages of competition and 50m splits were assessed using a Friedman test and if significant, multiple Wilcoxon tests were used post hoc. For all test's significance was set at $p<0.05$.

Effect sizes (ES) were calculated for all significant results by dividing the z score by the square root of the total sample size and were interpreted as small ($r = 0.10$), moderate ($r = 0.30$) and large ($r = 0.50$).

## 3. Results

### *3.1 Pacing Strategy - Split Times*

In all strokes, stages of competition and final race position split 1 was significantly faster ($p<0.05$) than splits 2,3 and 4 (table 2), with large effect sizes shown (ES = 0.86-0.88) (appendix 7). Split 2 was significantly faster ($p<0.05$) than split 3 in all strokes, stages of competition and final race position (ES = 0.50-0.88) except breaststroke medallists. Split 2 was significantly faster ($p<0.05$) than split 4 in all strokes, final race positions and stages of competition with large effect sizes reported (ES = 0.51-0.87). Although, backstroke non-medallists and freestyle medallist's semi-final reported no significant differences. Generally, backstroke and freestyle showed no significant differences between splits 3 and 4. Except backstroke semi-finals which reported split 4 was significantly faster ($p<0.05$) than split 3 regardless of final race position (ES = 0.41-0.52). Secondly, in freestyle medallist's (semi-final) split 4 was significantly faster ($p<0.05$) than 3 (ES = 0.49). Whereas, in breaststroke and butterfly, split 3 was significantly faster ($p<0.05$, ES = 0.54-0.81) than 4 in all stage of competitions and final race positions, excluding butterfly non-medallists.

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**Table 2.** Average (M ± SD) split times (seconds) in all competitions.

| | | Medallists Heat Time (Secs) | Medallists Semi-final Time (Secs) | Medallists Final Time (Secs) | Non-Medallists Heat Time (Secs) | Non-Medallists Semi-final Time (Secs) | Non-Medallists Final Time (Secs) |
|---|---|---|---|---|---|---|---|
| Backstroke | 0-50m | 30.27 ± 0.45[abc] | 30.16 ± 0.53[abc] | 29.87 ± 0.47[abc] | 30.63 ± 0.36[abc] | 30.45 ± 0.37[abc] | 30.28 ± 0.42[abc] |
| | 50-100m | 32.17 ± 0.36[de] | 31.97 ± 0.30[de] | 31.76 ± 0.38[de] | 32.54 ± 0.34[de] | 32.41 ± 0.36[d] | 32.35 ± 0.34[de] |
| | 100-150m | 32.75 ± 0.32 | 32.57 ± 0.27[f] | 32.23 ± 0.36 | 32.96 ± 0.30 | 32.81 ± 0.31[f] | 32.86 ± 0.36 |
| | 150-200m | 32.66 ± 0.35 | 32.31 ± 0.37 | 32.31 ± 0.57 | 32.95 ± 0.48 | 32.62 ± 0.42 | 33.03 ± 0.57 |
| | Final Time | 127.84 ± 0.82 | 127.01 ± 0.82 | 126.17 ± 0.90 | 129.08 ± 0.70 | 128.30 ± 0.78 | 128.52 ± 1.03 |
| Breaststroke | 0-50m | 33.28 ± 0.65[abc] | 32.84 ± 0.57[abc] | 32.76 ± 0.33[abc] | 33.27 ± 0.47[abc] | 32.92 ± 0.48[abc] | 32.87 ± 0.54[abc] |
| | 50-100m | 36.74 ± 0.60[e] | 36.15 ± 0.49[e] | 35.92 ± 0.47[e] | 36.80 ± 0.48[de] | 36.44 ± 0.46[de] | 36.43 ± 0.35[de] |
| | 100-150m | 36.80 ± 0.60[f] | 36.35 ± 0.42[f] | 36.07 ± 0.41[f] | 37.24 ± 0.48[f] | 36.88 ± 0.40[f] | 36.87 ± 0.48[f] |
| | 150-200m | 37.23 ± 0.70 | 36.89 ± 0.60 | 36.75 ± 0.85 | 37.59 ± 0.67 | 37.29 ± 0.48 | 37.51 ± 0.92 |
| | Final Time | 144.05 ± 1.66 | 142.22 ± 1.17 | 141.49 ± 1.27 | 144.90 ± 1.44 | 143.53 ± 1.00 | 143.67 ± 1.37 |
| Butterfly | 0-50m | 28.76 ± 0.47[abc] | 28.52 ± 0.47[abc] | 28.40 ± 0.40[abc] | 28.85 ± 0.34[abc] | 28.68 ± 0.35[abc] | 28.73 ± 0.44[abc] |
| | 50-100m | 32.67 ± 0.29[de] | 32.40 ± 0.30[de] | 32.01 ± 0.34[de] | 32.61 ± 0.40[de] | 32.25 ± 0.78[de] | 32.40 ± 0.43[de] |
| | 100-150m | 32.98 ± 0.31 | 32.87 ± 0.26 | 32.38 ± 0.31 | 33.08 ± 0.35[f] | 32.89 ± 0.28[f] | 32.73 ± 0.33[f] |
| | 150-200m | 33.22 ± 0.57 | 32.87 ± 0.52 | 32.59 ± 0.48 | 33.40 ± 0.46 | 33.13 ± 0.37 | 33.23 ± 0.76 |
| | Final Time | 127.63 ± 0.51 | 126.66 ± 0.47 | 125.38 ± 0.60 | 127.93 ± 0.72 | 126.95 ± 0.94 | 127.09 ± 0.88 |
| Freestyle | 0-50m | 27.43 ± 0.36[abc] | 27.33 ± 0.41[abc] | 27.16 ± 0.31[abc] | 27.51 ± 0.33[abc] | 27.35 ± 0.38[abc] | 27.17 ± 0.37[abc] |
| | 50-100m | 29.34 ± 0.71[de] | 29.33 ± 0.28[d] | 29.02 ± 0.34 [de] | 29.61 ± 0.28[de] | 29.48 ± 0.25[de] | 29.32 ± 0.20[de] |
| | 100-150m | 30.01 ± 0.25 | 29.74 ± 0.19[f] | 29.46 ± 0.25 | 30.12 ± 0.26 | 29.89 ± 0.29 | 29.98 ± 0.32 |
| | 150-200m | 29.85 ± 0.40 | 29.51 ± 0.40 | 29.48 ± 0.31 | 29.98 ± 0.40 | 29.79 ± 0.36 | 30.10 ± 0.70 |
| | Final Time | 116.62 ± 1.09 | 115.92 ± 0.67 | 115.12 ± 0.70 | 117.22 ± 0.60 | 116.51 ± 0.55 | 116.56 ± 0.78 |

Note: significant difference between [a] 0-50m and 50-100m, [b]0-50m and 100-150m, [c]0-50m and 150-200m, [d]50-100m and 100-150m, [e]50-100m and 150-200m, [f]100-150m and 150-200m.

*3.2 Normalised Velocity - Final Race Position*

Medallists completed races faster than non-medallists (table 2), however, as evidenced in figure 1 similar pacing strategies were used by both regardless of stage of competitions and stroke types, with no significant differences reported (appendix 7). Although, in breaststroke final non-medallists showed significantly higher split 1 normalised velocity compared to medallists ($p<0.05$, ES = 0.35). Whereas, breaststroke medallists showed significantly higher ($p<0.05$) normalised velocity (split 3) in all stages of competitions with moderate effect sizes reported (ES = 0.32-0.37). Finally, in freestyle final split 1 reported significantly higher normalised velocity for non-medallists ($p<0.05$, ES = 0.42).

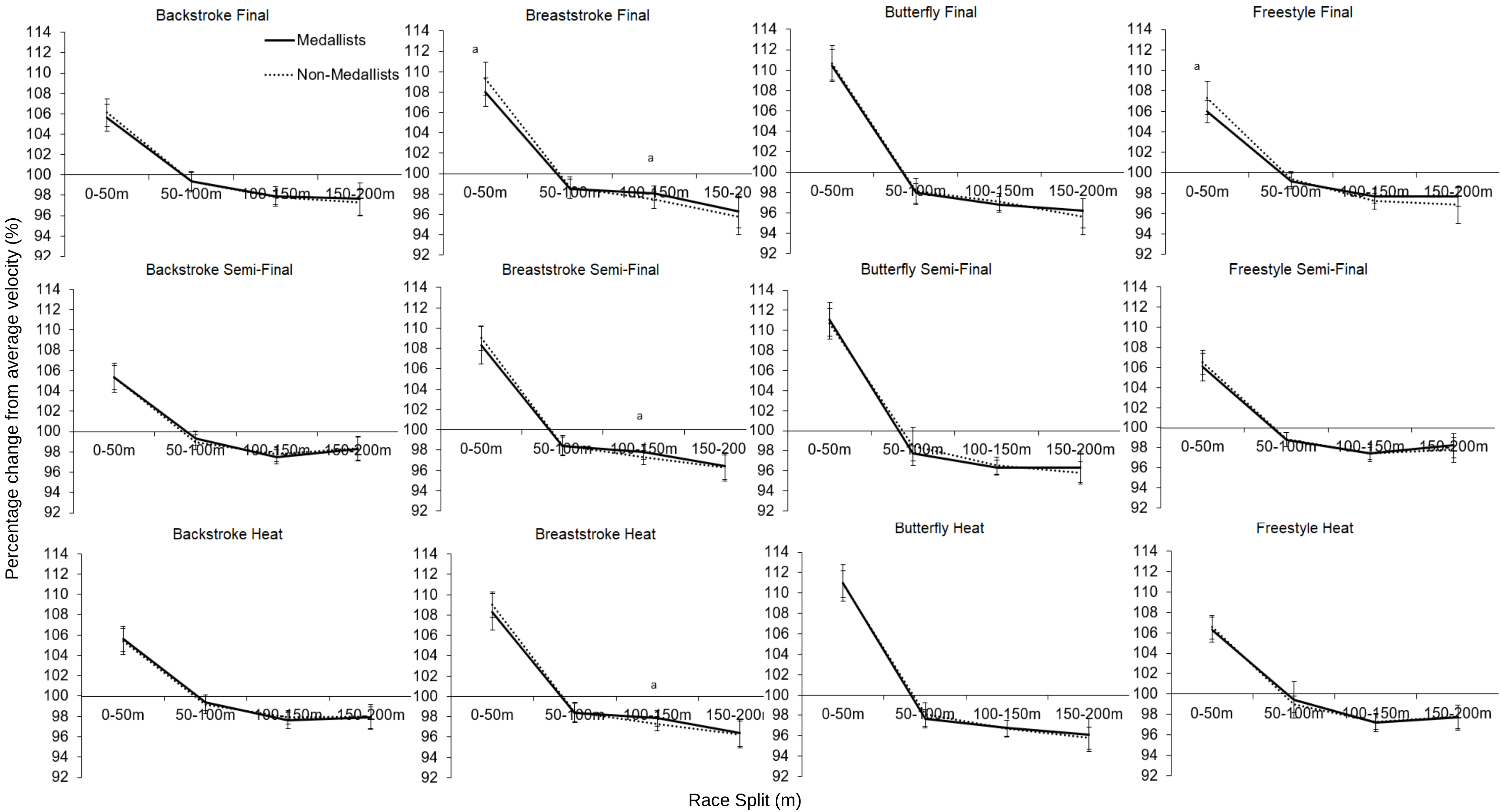


**Figure 1.** Normalised velocity pacing strategies comparing medallists and non-medallists.

Note: [a] significant difference between medallists and non-medallists.

*3.3 Normalised Velocity - Stage of Competition*

For medallist's race times improved as the stage of competition progressed, however, for non-medallist's performance peaked in semi-finals (table 2). Similar pacing was used (figure 2 and appendix 7) regardless of stage of competition in most strokes and final race positions as frequently, no significant differences were reported. There were some exceptions, significantly higher normalised velocity was reported in split 3 heats compared to semi-final for butterfly medallists ($p<0.05$, ES = 0.48). Secondly, backstroke (split 1 & 4), breaststroke (split 1) and freestyle (split 1, 2 & 4) non-medallists showed significant differences between heats and finals ($p<0.05$, ES = 0.39-0.50). Significant differences were also evidenced between semi-finals and finals for backstroke non-medallists (split 1 & 4), freestyle medallists (split 4), freestyle non-medallists (split 1, 2 & 4), and butterfly medallists/non-medallists (split 3) ($p<0.05$, ES = 0.40-0.65).

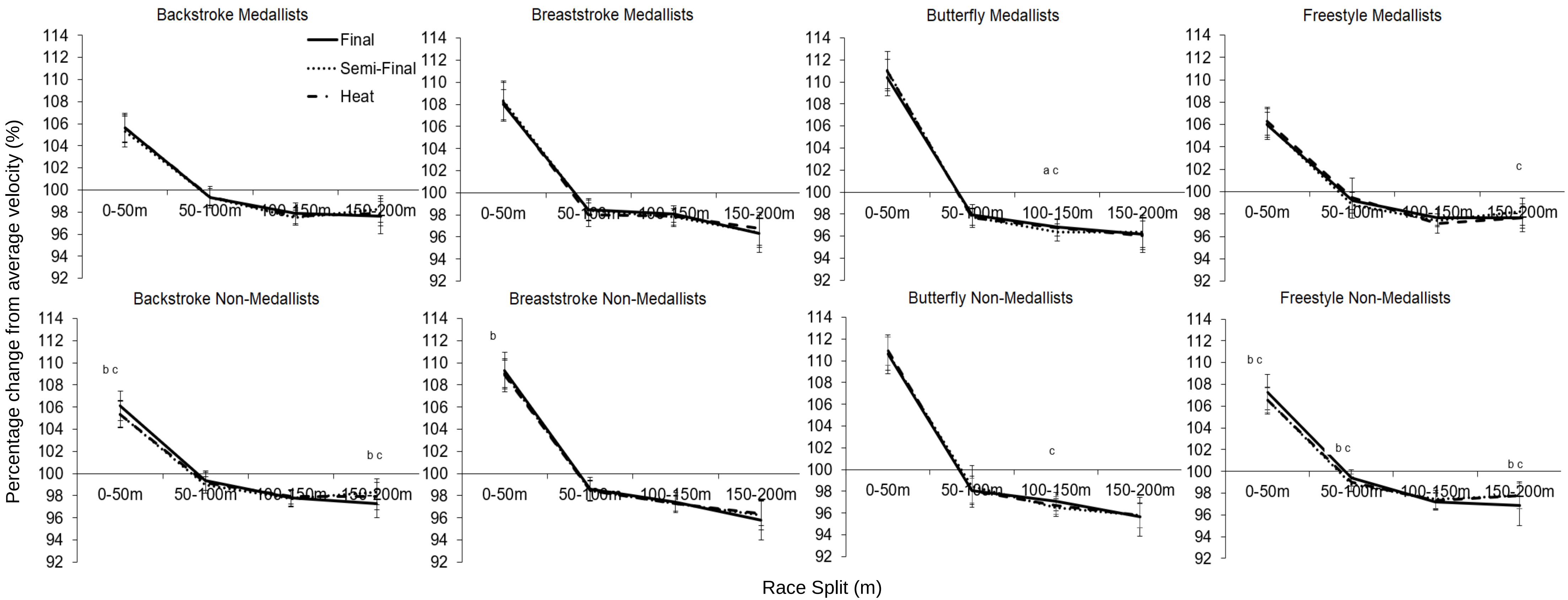


**Figure 2**. Normalised velocity pacing strategies comparing stages of competitions.

Note: Significant difference between [a] heat and semi-final [b] heat and final [c] semi and final.

*3.4 Normalised Velocity – Stroke Type*

Generally, similar pacing was reported in all strokes, characterised by a fast start. However, significant differences between the strokes indicate changes in pacing (figure 3 and appendix 7). Regardless of the stage of competition and final race position, significant differences (a-f) were reported between all stroke types ($p<0.05$), with moderate to large effect sizes reported (ES = 0.33-1.10) (figure 3 and appendix 7).

There were exceptions, with no significant differences reported between backstroke and breaststroke medallists (split 3) in all stages of competition. Similarly, between backstroke and freestyle, no significant differences were reported for medallists in all stages of competitions and splits (expect semi-final split 2) and for non-medallists (split 2 and 4) in all stages of competition and semi-final split 3. When comparing breaststroke to butterfly, no significant differences were reported in split 3 for non-medallists final, secondly, regardless of final race position and stage of competition no significant differences were reported in splits 2 and 4 (except medallist's semi-final split 2). Comparisons between breaststroke and freestyle reported no significant differences in split 2 (semi-finals) and split 3 regardless of final race position and stage of competition (except medallist's heats). Finally, no significant differences were reported between butterfly and freestyle in split 1 for non-medallist's heats, split 3 for medallist's heats and split 3 for non-medallists final.

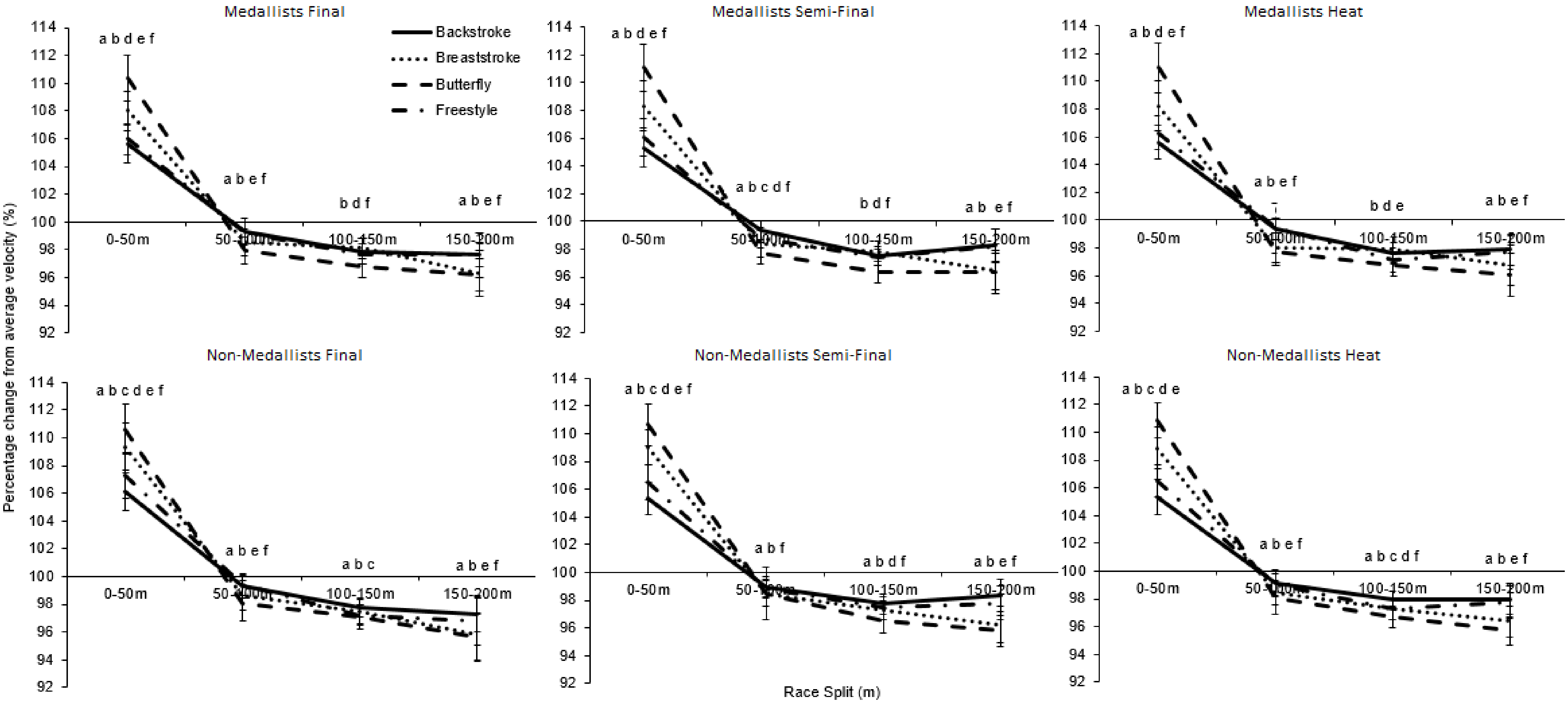


**Figure 3.** Normalised velocity pacing strategies comparing stroke types.

Note: Significant difference [a] backstroke and breaststroke [b] backstroke and butterfly [c] backstroke and freestyle [d] breaststroke and butterfly [e] breaststroke and freestyle [f] butterfly and freestyle.

*3.5 Pacing Strategy - Stroke Rate and Stroke Length*

As evidenced in table 3 highest average SR was reported in butterfly and highest average SL reported in breaststroke and freestyle, across the splits SR and SL both change significantly (appendix 7). In general, significant differences (a-f) were seen between all splits ($p<0.05$), with small to large effect sizes reported (ES = 0.10-0.51) (table 3 and appendix 7). There were exceptions with no significant differences between split 1 and 2 for breaststroke and freestyle SL. Secondly, no significant differences were reported between splits 1 and 3 in backstroke and freestyle SL and breaststroke SR. Additionally, no significant differences were reported between splits 1 and 4 in butterfly and freestyle SR. Finally, no significant differences were reported between splits 2 and 3 in backstroke and freestyle SR.

**Table 3.** Average stroke rate and stroke length in all competitions.

| | | Stroke Rate (stroke·min$^{-1}$) M ± SD | Stroke Length (m·stroke$^{-1}$) M ± SD |
|---|---|---|---|
| Backstroke | 0-50m | 45.06 ± 3.49 $^{abc}$ | 2.13 ± 0.15 $^{ac}$ |
| | 50-100m | 42.27 ± 3.31 $^{e}$ | 2.17 ± 0.17 $^{de}$ |
| | 100-150m | 42.42 ± 2.90 $^{f}$ | 2.13 ± 0.15 $^{f}$ |
| | 150-200m | 44.00 ± 2.61 | 2.01 ± 0.15 |
| | Average | 43.44 ± 2.92 | 2.11 ± 0.15 |
| Breaststroke | 0-50m | 36.00 ± 5.02 $^{ac}$ | 2.39 ± 0.29 $^{bc}$ |
| | 50-100m | 34.36 ± 3.33 $^{de}$ | 2.39 ± 0.21 $^{de}$ |
| | 100-150m | 38.16 ± 4.67 $^{f}$ | 2.16 ± 0.24 $^{f}$ |
| | 150-200m | 45.50 ± 5.30 | 1.79 ± 0.20 |
| | Average | 38.50 ± 3.52 | 2.18 ± 0.19 |
| Butterfly | 0-50m | 53.28 ± 2.00 $^{ab}$ | 1.84 ±0.06 $^{abc}$ |
| | 50-100m | 51.06 ± 1.58 $^{de}$ | 1.80 ± 0.05 $^{de}$ |
| | 100-150m | 51.69 ± 1.61 $^{f}$ | 1.77 ± 0.06 $^{f}$ |
| | 150-200m | 52.87 ±1.48 | 1.70 ± 0.05 |
| | Average | 52.22 ± 1.51 | 1.78 ± 0.05 |
| Freestyle | 0-50m | 47.88 ± 3.99 $^{ab}$ | 2.27 ± 0.31 $^{c}$ |
| | 50-100m | 45.46 ± 3.68 $^{e}$ | 2.23 ± 0.16 $^{de}$ |
| | 100-150m | 45.73 ± 2.27 $^{f}$ | 2.17 ± 0.10 $^{f}$ |
| | 150-200m | 47.28 ± 2.45 | 2.07 ± 0.10 |
| | Average | 46.58 ± 2.97 | 2.18 ± 0.14 |

Note: Significant difference between $^{a}$ 0-50m and 50-100m, $^{b}$ 0-50m and 100-150m, $^{c}$ 0-50m and 150-200m, $^{d}$ 50-100m and 100-150m, $^{e}$ 50-100m and 150-200m, $^{f}$ 100-150m and 150-200m.

*3.6 Normalised Stroke Rate and Stroke Length – Stroke Type*

Differences between the stokes were evidenced in both SR and SL (figure 4 and appendix 7). Significant differences were reported between backstroke and breaststroke in splits 1, 2 and 4 for SR and SL ($p<0.05$, ES = 0.68-0.80). Secondly, when comparing backstroke to butterfly significant differences were reported for SR (splits 1 & 3) and SL (splits 1, 2 & 3) ($p<0.05$, ES = 0.35-0.47). Between backstroke and freestyle no significant differences were reported. Contrastingly, breaststroke and butterfly reported significant differences in SR and SL in all splits ($p<0.05$, ES = 0.38-0.81) except SL in split 3. Additionally, significant differences were reported between breaststroke and freestyle for SR and SL (splits 1, 2 & 4) ($p<0.05$, ES = 0.00-0.82). Finally, significant differences in SL were reported in split 2 between butterfly and freestyle ($p<0.05$, ES = 0.39).

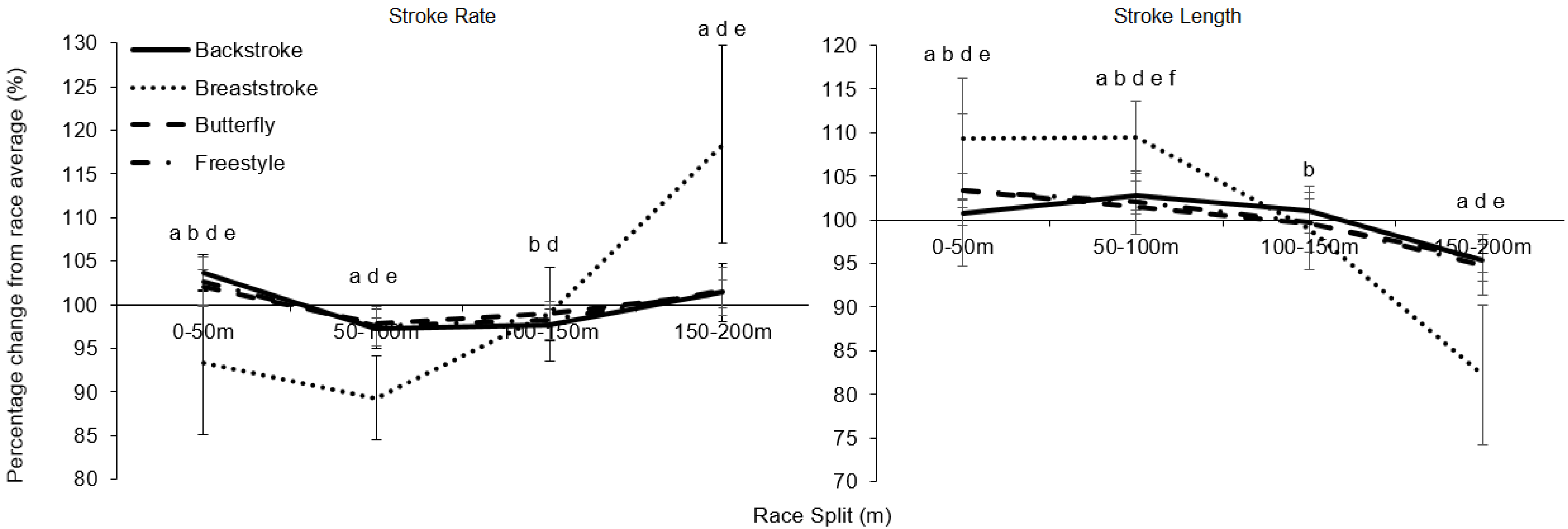


**Figure 4**. Normalised stroke rate and stroke length comparing stroke types.

Note: Significant differences between [a] backstroke and breaststroke [b] backstroke and butterfly [c] backstroke and freestyle [d] breaststroke and butterfly [e] breaststroke and freestyle [f] butterfly and freestyle.

## 4. Discussion

This study aimed to investigate the effect of final race position, stage of competition and stroke type on pacing strategy in elite women's 200m swimming performance and to appraise medallists SR and SL. The main findings showed 'fast start-even' or 'positive' pacing strategy regardless of final race position and stage of competition. Whereas, pacing strategies varied significantly between strokes, further evidenced by differences in SR and SL.

### *4.1 Pacing Strategy – Split Times*

Firstly, the pacing strategies were profiled using split times, in all strokes, stages of competition and final race positions split 1 was significantly (1.8-4.6 seconds) faster than splits 2, 3 and 4, with large effect sizes reported (table 2 and appendix 7). This illustrates 'fast start' pacing and supports previous research (Skorski et al., 2014; Stanula et al., 2016), more specifically, Robertson et al. (2009) showed split 1 to be 1.7-4.9 seconds faster than subsequent splits. The 'fast start/positive' pacing was a consequence of the dive start (Robertson et al., 2009; Skorski et al., 2014; Stanula et al., 2016). The dive generates a velocity of ~4 $m \cdot s^{-1}$ which is over twice the average velocity ~1.57 $m \cdot s^{-1}$ in the current study, improving split 1 time by ~1-3 seconds (Kiuchi et al., 2010).

Similarly, split 2 was significantly faster than splits 3 and 4 indicating 'positive' pacing (table 2). This opposes previous studies which reported, 'fast start-even' (Robertson et al., 2009; Skorski et al., 2014; Stanula et al., 2016). The contrasting findings potentially owe to differing analysis, as raw data in previous research showed higher normalised velocity in split 2 compared to 3 and 4 (Skorski et al., 2014) and split 2 to be ~0.47-1.37 seconds faster than splits 3 and 4 (Robertson et al., 2009). These results were described as non-significant, however, less than one second distinguished medal positions (Mauger et al., 2012). Therefore, these findings could have practical importance. Additionally, Skorski et al. (2014) appraised male performance, therefore, contrasting results could owe to performance (Mauger et al., 2012; Robertson et al., 2009) and pacing (Saavedra et al., 2012) differences between genders.

In backstroke and freestyle no significant differences were reported between split 3 and 4, this indicates ‘even’ pacing and was accordance with previous research (Robertson et al., 2009; Skorski et al., 2014; Stanula et al., 2016). Whereas, in butterfly (non-medallists) and breaststroke split 3 was significantly faster than 4, this reinforces previous research suggesting ‘positive’ pacing in breaststroke (Thompson et al., 2000; Thompson et al., 2003, 2004). The conflicting findings between split 3 and 4 owe to increased performance variability later in races (McGibbon et al., 2018).

The increased variability was a consequence of fatigue (McGibbon et al., 2018), large quantities of the energy required for 200m performance is produced via anaerobic metabolism (Figueiredo, Rouard, Vilas-Boas & Fernandes, 2013), leading to high blood lactate concentrations 8.9-13.2 mmol·L (Conceição, Silva, Barbosa, Karsai & Louro, 2014; Thompson et al., 2003). The high blood lactate lowers muscular pH and increases the accumulation of hydrogen ions, which interfere with the muscle contraction mechanism (Stirn, Jarm, Kapus & Strojnik, 2011). Specifically, reducing the muscle fibre contraction velocity which is the speed of the action potential and changing the shape of the motor unit action potential waveform (Conceição et al., 2014). This decreases the swimmers muscular force production and therefore, leads to an inability to sustain SL which decreases velocity and increases split time (Stirn et al., 2011).

*4.2 Pacing Strategies - Stroke Rate and Stroke Length*

It was anticipated that changes in SR and SL would underpin the pacing strategy adopted. This was somewhat true, split 1 evidenced high SR and SL in all strokes compared to other splits (table 3). From split 2 onwards SL declined significantly in all strokes at each split, whereas, SR increased significantly from split 2 onwards (table 3). Given the well-established inverse relationship between SR and SL these findings were expect and support that of previous studies (Chatard, Caudal, Cossor & Mason, 2001a; Chatard, Girold, Cossor & Mason, 2001b; Huot-Marchand, Nesi, Sidney, Alberty & Pelayo, 2005; McGibbon et al., 2018).

In the first half of 200m races high SL was beneficial as higher propulsive forces can be generated (Hellard et al., 2008). This was possible because muscular fatigue was not present (Hellard et al., 2008). The disproportionately high SR and SL in the opening laps quickly leads to fatigue and declines in SL, owing to the previously described mechanism, which decreased muscular force production in the subsequent laps (Thompson et al., 2000). Muscular fatigue also leads to poor technique and poor body alignment which increases drag (Thompson et al., 2000). The higher drag and reduced force production lead to further decreases in SL because of increased resistance to forward movement which the swimmers cannot overcome (Huot-Marchand et al., 2005), these factors combine to increase split times.

Swimmers attempt to compensate for declines in SL by increasing SR (McGibbon et al., 2018), evidenced in both the current study and previous research (Thompson et al., 2000). The low SR reported in split 2 was potentially a tactical attempt to conserve energy for a sprint finish (Thompson et al., 2000), secondly, the increased SR from split 2 onwards ineffectively coped with fatigue and the declining SL, as split times continuously worsen. Coaches and athletes should consider utilising ‘fast start-even’ pacing strategies to delay muscular fatigue and declines in SL, therefore, preventing decline in split 4 performance (Thompson et al., 2000). Additionally, consideration of individualised and optimal SR and SL combinations is required to improve performance further (Huot-Marchand et al., 2005).

*4.3 Normalised Velocity – Final Race Position*

The success of swimmers is directly reflected in final race position, medallists complete 200m in less time using a higher average velocity than non-medallists (table 2). Normalised velocity enables interpretation beyond this basic observation. In general, no significant differences were reported between medallists and non-medallists, therefore, both utilise the same pacing strategies in all stroke types and stages of competition (figure 2). This supports the findings of Robertson et al. (2009) with differences in fitness and technique rather than pacing cited as reasons for successful or unsuccessful performance.

The findings were expected as coaches and athletes replicate pacing of world class/successful competitors, this approach was often unsuccessful with non-medallists reducing efforts in the latter stages (Hanley, 2014, 2018; McGibbon et al., 2018). This was evidenced in the present study, as non-medallists showed significantly higher normalised velocity in split 1 for breaststroke and freestyle finals, however, by split 3 medallists had significantly higher normalised velocity in breaststroke final (figure 1). These findings could be more pertinent to longer races as evidenced in 400m freestyle (Mytton et al., 2015) and cross country running (Hanley, 2014). The results described in backstroke and freestyle suggest non-medallists begin races at a velocity they cannot maintain (figure 1). This may be an attempt to gain a tactical advantage or disrupt the pacing of their competitors (McGibbon et al., 2018), however, this tactic was unsuccessful as swimmers compete in their own lane isolated from opposition which minimises the impact of competitors pacing strategies (Skorski et al., 2014).

Practically, this means swimmers should utilise pre-determined strategies (McGibbon et al., 2018), and non-medallists need to adopt other ways to improve performance. It was assumed that elite medallists would use the fastest pacing strategy (Mauger et al., 2012), however, more laboratory-based research is warranted to ensure optimal pacing is currently used for competition and training (McGibbon et al., 2018).

*4.4 Normalised Velocity – Stage of Competition*

Another important finding was regardless of final race position and stroke type no significant differences in pacing strategy were reported between heats, semi-finals and finals (figure 2), this supports previous research (McGibbon et al., 2018; Skorski et al., 2014). Elite swimmers have a high ability to consistently execute predetermined pacing strategies (McGibbon et al., 2018; Skorski et al., 2014). This owes to increased competitive experiences, previous performances are sorted within the long-term memory and used as schema for future performances (Skorski et al., 2014).

A distinguishing characteristic of medallists was an ability to progress performance, medallists produce peak performance in finals with non-medallists peaking in semi-finals (table 2). A performance progression between heats and finals of 1-1.3% is cited in previous research (McGibbon et al., 2018; Pyne et al., 2004). Changes in pacing were previously thought to be responsible for this progression (Pyne et al., 2004). However, tactical approaches were more likely to explain these differences, elite swimmers obtain lower average velocity in heats compared to finals (Skorski et al., 2014). This enabled energy conservation in the earlier stages of competition and best performance to be produced in finals where medal positions are decided (Skorski et al., 2014; Thompson et al., 2004). Although, caution is advised with this approach as swimmers must ensure qualification from heats to finals.

*4.5 Normalised Velocity – Stroke Type*

In comparison to both final race position and stage of competition, pacing strategies varied significantly between the strokes with moderate to large effect sizes reported (figure 3). The differences mostly resided when comparing alternating (backstroke/freestyle) and simultaneous (breaststroke/butterfly) strokes. Swimmers tended to adopt 'fast start-even' pacing in alternating strokes, whereas, 'positive' pacing was employed in simultaneous stokes (figure 3). This substantiates previous research indicating differences in pacing exist between strokes due to stroke mechanics (Hellard et al., 2008; Robertson et al., 2009).

Simultaneous strokes have lower mechanical efficiency with breaststroke being three times less efficient than freestyle (Thompson et al., 2004). The lower efficiency was due to reduced continuous motor effect, a less streamline body position (Hellard et al., 2008), and increased reliance on leg propulsion (Robertson et al., 2009). These factors all contribute to an increased energy cost per stroke (McGibbon et al., 2018). The higher energetic costs of simultaneous stroking lead to earlier fatigue, therefore, higher losses in velocity ('positive' pacing) in the later stages of races (McGibbon et al., 2018).

Secondly, alternating strokes utilise tumble turns which includes rotation time within first split, whereas, simultaneous strokes use touch turns which include rotation times within second split (McGibbon et al., 2018). This equates to a difference of ~1-2 seconds, despite having no impact on overall race time 50m splits were altered, this somewhat explains differences in pacing (McGibbon et al., 2018). Additionally, backstroke swimmers start in the water meaning a lower velocity from the dive start compared to other strokes (Robertson et al., 2009), therefore, relatively higher normalised velocity could be shown in the latter stages, meaning a more 'even' pacing strategy was evidenced (McGibbon et al., 2018).

*4.6 Normalised Stoke Rate and Stroke Length – Stroke Type*

To further explain the differences between strokes normalised SR and SL were included, this was a novel approach, therefore, comparing to previous research was somewhat limited. Significant differences were mostly reported between alternating and simultaneous strokes, with no significant differences reported between backstroke and freestyle (figure 4). This indicates stroke mechanics explained the pacing differences (Chollet et al., 1996; Hellard et al., 2008). Previous research highlighted higher SL in alternating arm strokes (Chatard et al., 2001a; Chatard et al., 2001b; Chollet et al., 1996; Hellard et al., 2008), this was caused by body roll which enables the swimmer to stretch further ahead and a longer upsweep when completing the stroke (Hellard et al., 2008), however, results from the current study do not support this (table 3).

One explanation for the differing results could be quantification method, with previous studies making comparisons using raw data (Chatard et al., 2001a; Chatard et al., 2001b; Hellard et al., 2008). Secondly, early studies (Chollet et al., 1996), calculated SL as velocity divided by SR leading to overestimations (Thompson et al., 2000). This was because non-swimming elements (e.g. dive start and turns) were included in the calculation, however, recent studies have corrected this (Thompson et al., 2000). Additionally, the current study was a contemporary appraisal (post 2010) which could explain differences between studies, as SR (Hellard et al., 2008) and performance (Partridge, 2011) have developed over time.

An important finding in normalised SR/SL was significantly lower SR/higher SL in splits 1 and 2, with higher SR/lower SL in split 4 for breaststroke compared to all other strokes (figure 4). The results were likely due to different mechanics with breaststroke swimmers utilising longer gliding phases, therefore, lowering the frequency of strokes and increasing the SL before fatiguing (Hellard et al., 2008). Coaches and athletes should consider adapting pacing strategies dependent on the stroke used. Breaststroke and butterfly swimmers could benefit from 'even' pacing to prevent declines in stoke parameters and maximise performance, however, further controlled investigation into the effect of these pacing methods is required (Thompson et al., 2000).

### *4.7 Limitations and Future Research*

There are several limitations within the present study, firstly, situational factors i.e. motivation, diet and training were not controlled, therefore, reducing the internal validity compared to laboratory-based experiments (Skorski et al., 2014). However, as with all observational descriptive studies using data from competitions high external validity was seen (Skorski et al., 2014). A second limitation of using official data was the low resolution, pacing was appraised every 25% of the race which was below the 5-10% recommendations, therefore, discrete changes in pacing may go unnoticed. (Foster, Schrager, Snyder & Thompson, 1994; Mauger et al., 2012). Another limitation was the inclusion of SR and SL pertaining only to medallists as the findings cannot be generalised to all swimmers. Finally, explaining pacing using SR and SL was limited as only the free swim elements of the race are considered (Huot-Marchand et al., 2005), future research should also consider non-swimming components (McGibbon et al., 2018).

Additionally, future research should also address male performances, physiological (Thibault et al., 2010), performance (Mauger et al., 2012; Robertson et al., 2009) and pacing (Saavedra et al., 2012) differences between genders are evidenced meaning the findings of the current study cannot be transferred directly to males. Finally, future research should improve control of the dive start, this could be achieved by using data with higher resolution enabling data before breakout to be removed.

### *4.8 Conclusion*

In conclusion, this study categorised elite women's 200m pacing as 'fast start-even' or 'positive', the pacing strategies were underpinned by the dive start and declines in SL as the race progressed. In line with the aims of the study pacing strategy was not influenced by final race position or stage of competition. Whereas, stroke type changed pacing strategy with 'fast start-even' utilised in backstroke and freestyle, and 'positive' used in breaststroke and butterfly. These differences owed to the stroke mechanics effecting fatigue which lead to changes in SR and SL. These findings have practical implications as recommended strategies for swimmers and coaches are updated. Moreover, careful consideration depending on stroke type and greater individualisation of SR and

SL required. Finally, alternative ways other than pacing strategy should be sought to improve performance from heats to finals to increase likelihood of success.

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**Appendices**

Appendix 1 – Pacing Strategies Definitions (see USB)

Appendix 2 – Ethical Approval (see USB)

Appendix 3 – British Swimming Consent (see USB)

Appendix 4 – Data Omissions (see USB)

Appendix 5 – Operational Definitions (see USB)

Appendix 6 – Reliability Testing (see USB)

Appendix 7 – SPSS and Effect Sizes (see USB)

Appendix 8 – Raw and Processed data (see USB)

Appendix 9 – Graphs (see USB)

Appendix 10 – SPSS Outputs (see USB)

Appendix 11 – Effect Size Calculations (see USB)

Appendix 12 – G*Power Calculation (see USB)